Summary of ICCR Source Work Group Meeting
July 24, 1997
Internal Combustion Engines Work Group Meeting

I. Purpose

The main objectives of the meeting were to agree on a Generic Test Protocol, develop preliminary lists of types of engines and control devices to be tested, develop a preliminary prioritization scheme for testing, identify a strategy to approach blank control device codes, determine whether the EPA ICCR database contains adequate information for subcategorization, assess the progress of each of the subgroups and identify new tasks which need to be addressed by the work group.

II. Location and Date

The meeting was organized by the Environmental Protection Agency (EPA) and was held at the Renaissance Hotel in Long Beach, California. The meeting took place on July 24, 1997.

III. Attendees

Meeting attendees included representatives of the OAQPS Emission Standards Division, trade associations, universities, and state agencies. A complete list of attendees, with their affiliations, is included as Attachment I.

IV. Summary of Meeting

The meeting consisted of discussions between WG members on selected issues which are listed below. The order of the meeting followed the agenda provided in Attachment II. A bullet point summary of the meeting is presented as Attachment III.

The topics of discussion included the following:

- Highlights of the Recent Coordinating Committee Meeting
- Emissions Subgroup Report and Remaining Test Plan Issues
- Population Database Enhancement Activities
- Population and Structure Subgroup Report
- MACT Floor Issues
- Next Meeting

Highlights of the Recent Coordinating Committee Meeting

Vick Newsom relayed highlights from the Coordinating Committee Meeting. These items were provided in the CC Meeting Flash Minutes as a handout, and can be downloaded from the TTN. One pertinent topic of discussion addressed the RICE WG specifically; the RICE proposed list of pollutants was not approved, and the RICE WG was directed to consider dioxin, mercury, and criteria pollutants. These issues will be revisited at a future CC meeting.

Emissions Subgroup Report: Status of the RICE Test Plan and Remaining Test Plan Issues

S. Clowney presented a report on the RICE Test Plan from the Emissions Subgroup. He also made a presentation giving the RICE WG a guide for discussion, entitled "RICE Test Plan: WG Discussion and Decision-making on Remaining Issues." A copy of each of these presentations are included as Attachment IV.

The topics of discussion which followed included the HAPs list, the generic test protocol, test methods, categories of RICE, fuels and control devices to be tested, and prioritization.

HAPS List

The most recent CARB documentation was released in the last few months. In the process of developing their list of HAPs, CARB created a criteria which the RICE WG may be able to use as a guide for further developing their own list of pollutants. Don Price volunteered to obtain this documentation for the use of the RICE WG.

In response to the CC's concern about dioxin and mercury, the WG decided to perform a literature search to resolve these issues, and to enlist outside expertise to create a "white paper" on the topic. Reese Howle stated that a literature search can be performed through the EPA library. A Dioxin Subgroup was formed, headed by Amanda Agnew. Its members will include Bill Passie, Mike Brand, Mike Milliet, Bryan Willson and Sam Clowney.

Some work group members stated that fuel analysis for chlorine was not adequate for determination of the possibility of dioxin emissions, since dioxins may be formed by the breakdown of lubricating oils for the engines.

Others raised the issue that if the WG is looking at total HAPs, dioxin is just a small part.

Ed Torres stated that tests performed for AB2588 for digester gas fired engines gave readings of “no detect” for dioxin.

Bill Passie presented a handout of pollutants from the CARB list from digester gas fired engines. These included: 1,3-butadiene, acrolein, benzene, formaldehyde, methylene chloride, tetrachloroethylene (perchloroethylene), toluene, trichloroethylene, and xylene.

The Testing and Monitoring Work Group has been requested to provide an explanation for the selection of digester gas pollutants, including sources for their emissions information.

The Emissions Subgroup will follow up on the Coordinating Committee’s request for input into the list of pollutants for RICE.

Generic Test Protocol

The WG came to a consensus on the acceptance of the Generic Test Protocol. It is included as Attachment V.

Test Methods

Sam Clowney emphasized the need to have on-site measurements. He stated that although these measurements may be more expensive, they would be more accurate, and would prevent retesting later. Getting emissions results in real time may be less costly in the long run, since the tests could be rerun immediately on-site instead of returning later, after wet lab analyses were performed.

The Emissions Subgroup plans to prepare a revised list of test methods, with costs to address the need for real-time data. They plan to begin this review by August 15th.

The Testing and Monitoring Work Group has been requested to provide information on test methods that can provide real-time data for IC engines, since all test methods included in the recent memo require laboratory analysis prior to knowing the results.

Categories of RICE, Fuels and Control Devices to be tested

Don Dowdall presented two trees illustrating potential ICCR engine subcategories and existing/potential control technologies for reducing emissions. There was a separate tree for gaseous fuels and diesel fuel. Don noted that he included all add-on controls and did not try to assess whether or not the controls affect HAPs. These tree diagrams were handed out at the meeting, and may be obtained by contacting Don Dowdall at (309) 346-0683. Jay Martin suggested looking at advanced fuel injection as a control for diesel engines.

The Emissions Subgroup will prepare lists of RICE and controls for emissions testing under ICCR using Don Dowdall's handouts for liquid and gaseous fuels. They plan to begin this review by August 15th.

Prioritization

The WG discussed possible inputs into a prioritization methodology. Amanda Agnew of EPA indicated that EPA will give the highest priority to tests that identify control devices or control techniques that may reduce HAP emissions, and that the RICE WG must justify each emission test it recommends to the Coordinating Committee. The following other inputs for prioritization were discussed during the meeting:

* The subcategory of engine represents a significant portion of the existing population.

* The emissions from the category are significant when compared to emissions from the entire population of engines or when compared to other individual engines.

* The type of control device has broad applicability -- may be used for more than one subcategory of engine or may be used to extrapolate or interpolate for a subcategory that represents a significant portion of the existing population.

* The engine or fuel type represents a data gap that cannot be addressed through emission factors, engineering calculations, etc., with the existing emissions database.

Other Discussion

Ed Torres stated his opinion that a backup plan is needed in the case that funding is not available for such extensive testing as indicated in the test plan. Reese Howle indicated that even if the MACT floor is determined to be "no control", emission limits may need to be set. Bryan Willson asked whether pollutants included on the list for testing, such as the chlorinated compounds for natural gas, would be included as emission limits in the MACT. Amanda Agnew noted that the MACT may not necessarily include an emission limit for all the pollutants included in testing. Sam Clowney also noted that the current pollutant list is for the purposes of emissions testing only.

Vick Newsom stated that the WG should determine the minimum amount of data necessary for the test data to be useable.

The Emissions Subgroup plans to prepare a preliminary prioritization methodology incorporating the comments received at this meeting. They plan to begin this effort by August 29th.

Population Database Enhancement Activities

Jennifer Snyder of Alpha-Gamma Technologies presented a report on the Population Database enhancement activities. This is included as Attachment VI.

MACT Floor Issues

Four main issues were raised regarding the data in the Population Database: 1)blanks in the control device codes counting as “no control”, 2)statistical adequacy of the data, 3) gathering of engine make and model information, and 4) feasibility of engine subcategorization.

Blanks in the Control Device Code Field

The issue was raised as to whether blanks in the control device field should be counted as “no controls.” A breakdown of control devices in the population database for each subcategory was given, using two criteria: with and without blanks. This was presented as material for a draft form for a preliminary MACT floor.

Statistical Adequacy of the Data

Some WG members regarded the data in the Population Database as not representative of the real world. The WG decided that a better way to look at control device codes was by size and geographical distribution, for comparison purposes. This work will be performed by Alpha-Gamma before the next meeting. Vick

Newsom spoke for API, saying that their database will not be ready by September as originally scheduled. Once this database is ready it can be merged with the existing population database for a more complete look at the inventory. The general consensus was that there is currently not enough information to give a preliminary MACT floor. The RICE WG will wait until the November meeting to present engine subcategories with MACT floor determinations to the CC.

Gathering of Make and Model Information

Alpha-Gamma requested that WG members review the list of makes and models for which engine parameters are not known and provide information where possible.

Feasibility of Engine Subcategorization

Many work group members felt it was premature to determine engine subcategories, based on the general consensus of lack of data in the current Engines Population database.

Next Meeting

The next Internal Combustion Work Group Meeting will be in Durham, NC on Thursday, September 18, 1997, starting at 8:00 a.m. EST. The determination of the next co-chair and alternate will be on the agenda. The current co-chair and alternate have indicated that they are willing to serve another term, if the WG exhibits this desire. All WG members are encouraged to submit nominations for a new co-chair or alternate to Amanda Agnew, preferably by e-mail, by August 31. The population subgroup will also make a presentation at the next meeting, giving updates to data in the population database.

These minutes represent an accurate description of matters discussed and conclusions reached and include a copy of all reports received, issued, or approved at the July 24, 1997 meeting of the Reciprocating Internal Combustion Engines Work Group.

Amanda Agnew

ATTACHMENT I

LIST OF ATTENDEES

Stationary Internal Combustion Engines Work Group Meeting
July 24, 1997
List of Attendees

Amanda Agnew	EPA OAQPS Emissions Standards Division
Alec Atanas	Englehard Corporation
Michael Brand	Cummins Engine Co., Inc.
Sam Clowney	Tenneco Energy
Donald Dowdall	Engine Manufacturers Association
Rand Drake	US Naval Facilities Engineering Service Center
Charles Elder	General Motors Corporation
Wayne Hamilton	Shell E&P Technology Company
William Heater	Cooper Energy Services
Jay Martin	University of Wisconsin-Madison
Michael Milliet	Texaco E&P Inc.
Vick Newsom	Amoco Production Section
William Passie	Caterpillar, Inc.
Donald Price	Ventura County Air Pollution Control District
Ed Torres	Orange County Sanitation District
Bryan Willson	Colorado State University
Jan Connery	Eastern Research Group
Reese Howle	Alpha Gamma Technologies
Jennifer Snyder	Alpha Gamma Technologies
Lisa Beal	INGAA
Atly Brasher	Louisiana DEQ
Linda Coerr	Coerr Environmental
Richard Crume	Environmental Protection Agency
Richard Lee Fuller	McDonnell Douglas - MTA Environmental
Terry Harrison	EPA
Tim Hunt	American Petroleum Institute

Dennis Knisley	Eastman Chem Co. (TMPWG)
Karl Loos	Shell (TMPWG)

ATTACHMENT II

JULY 24, 1997 MEETING AGENDA

Agenda
Reciprocating Internal Combustion Engine Work Group
July 24 WG Meeting - Long Beach, CA

8:30 - 8:45 Welcome, Meeting Goals (A. Agnew)
Agenda Review (J. Connery)

I- Emissions Subgroup:
- Agree on generic Test Protocol
- Decide how to test (not-test) Naphthalene and POM(PAHs)
- Develop preliminary list of types of engines and control devices to be tested
- Develop preliminary prioritization scheme for testing funds

II- Population Subgroup
- Identify strategy to approach blank control device codes
- Determine whether ICCR database has adequate information to subcategorize engines into 2-stroke and 4-stroke/rich or lean burn

8:45 - 9:15 Outcome of the CC Meeting (V. Newsom and A. Agnew)

9:15 - 9:45 Emissions Subgroup Report (S. Clowney)
- Status of the RICE Test Plan

9:45 - 10:30 WG Discussion and Decision Making Regarding Remaining Test Plan Issues
- Types of engines and control devices to be tested

10:30 -10:45 BREAK

10:45 - 11:45 WG Discussion and Decision Making Regarding Remaining Test Plan Issues (cont'd.)
- Testing for Naphthalene and POM (PAHs)
- Testing for Dioxin and Chlorinated Hydrocarbons
- Final determination of test methods for HAP measurements
- Next steps

11:45- 1:00 LUNCH

1:00 - 2:00 Population Database Enhancement Activities (J. Snyder)
- Clean up procedures
- Extracted information
- Short list of fields
- Revised population flow chart

2:00 - 3:00 Population and Structure Subgroup (W. Hamilton)
- Status and goals
- Strawman for validating information

3:00 - 3:15 BREAK

3:15 - 4:00 WG Discussion and Decision Making Regarding MACT Floor Issues
- Handling of Blank and Zero control device codes
- Status of gathering Engine Make and Model information
- Feasibility of engine subcategorization (2&4 Stroke/Rich & Lean Burn)
- Next steps

4:00 - 4:15 Next Meeting (A. Agnew and J. Connery)
- Schedule
- Tentative agenda items

4:15 - 4:30 Review of Flash Minutes (J. Connery and J. Snyder)

4:30	ADJOURN

ATTACHMENT III

BULLET POINT SUMMARY

Summary of ICCR Source Work Group Meeting, July 24, 1997
Internal Combustion Engines Work Group Meeting
Renaissance Hotel, Long Beach, CA

Decisions

- Consensus on performing a literature search to resolve the dioxin and mercury issues, and to enlist outside expertise to create a “white paper” on the topic.
- Consensus on acceptance of the “Generic Test Protocol.”
- Consensus to wait until the November meeting to present engine subcategories with MACT floor determinations to the CC.
- A Dioxin Subgroup was formed, headed by A. Agnew. Its members will include Bill Passie, Mike Brand, Mike Milliet, Bryan Willson and Sam Clowney.

Next Meeting

- The next Internal Combustion Work Group Meeting will be held in Durham, NC on Thursday, September 18, 1997 starting at 8:00 a.m. EST.
- Determination of next co-chair and alternate will be performed at the next meeting.

Action Items

- D. Price: Obtain the most recent CARB documentation for background information on HAPS list determination.
- Alpha-Gamma: Determine engine distribution in the population database based on geographical location and engine capacity.
- Population Subgroup: Give a presentation on updates to data at the next WG meeting.
- All WG members: E-mail A. Agnew with nominations for a new co-chair or alternate by August 31.
- Emissions Subgroup: Follow-up on Coordinating Committee's request for input into list of pollutants for RICE.
- Emissions Subgroup: Prepare lists of RICE and controls for emissions testing under ICCR using Don Dowdall's handouts for liquid and gaseous fuels. Subgroup to begin review by August 15th.
- Emissions Subgroup: Prepare revised list of test methods, with costs, to address need for real-time data. Subgroup to begin review by August 15th.
- Emissions Subgroup: Prepare preliminary prioritization methodology incorporating comments received at Work Group meeting. Subgroup to begin review by August 29th.
- Testing and Monitoring Work Group: Provide explanation for selection of digester gas pollutants, including source for emissions information.
- Testing and Monitoring Work Group: Provide information on test methods that can provide real-time data for IC engines, since all test methods included in recent memo require laboratory analysis prior to knowing the results.

ATTACHMENT IV

REPORT ON THE RICE TEST PLAN FROM THE EMISSIONS SUBGROUP AND RICE TEST PLAN: WG DISCUSSION AND DECISION MAKING ON REMAINING ISSUES

PRESENTED BY SAM CLOWNEY

Report on the RICE Test Plan from the Emissions Subgroup

presented to:

Reciprocating IC Engine Work Group
Long Beach, California

presented by:

Sam Clowney, Tennessee Gas Pipeline, on behalf of
the Emissions Subgroup

July 24, 1997

RICE Test Plan

- Goal for the Test Plan:
  - To identify emissions tests and funding necessary to fill data gaps in the RICE emissions database

- Components of the Test Plan:
  1. Pollutants to be measured
  2. Protocol to document RICE engineering and operating parameters during emissions testing
  3. Test methods that will be used to quantify HAPs and criteria pollutants (working with T&M Work Group)
  4. Categories of RICE, fuels, and control devices to be tested
  5. Methodology to prioritize emissions testing if limited testing funds are available

List of Pollutants (1)

- Goal for List of Pollutants:
  - Identify all pollutants that will be measured in emissions tests for RICE under ICCR, using the best information available to the ICCR process
- Status:
  - Final lists include all pollutants reported as "detects" in the ICCR emissions database for RICE
  - Work Group consensus, at May meeting, on lists of pollutants, pending resolution of the dioxin issue
  - Work Group presentation to Coordinating Committee,
    July 23, 1997

List of Pollutants (2)

- Outstanding Issues:
  - Comparison lists for digester gas, landfill gas, and propane from the Testing & Monitoring Work Group
  - Resolution of dioxin issue
    - Literature search under way --most information on dioxin from municipal waste combustors and incinerators
    - Goal for literature search: to identify factors in dioxin formation in order to determine if dioxin can be reasonably anticipated from RICE

Proposed Pollutants for Emissions Tests Under ICCR

Pollutant	Diesel Fuel	Digester Gas	Landfill Gas	Natural Gas	Propane
1,1,2,2-Tetrachloroethane				X	
1,1,2-Trichloroethane					
1,3-Butadiene	X			X	
1,3-Dichloropropene					
1,4-Dichlorobenzene(p)		X			
1,4-Dioxane					
Acetaldehyde	X	X	X	X	X
Acrolein	X	X	X	X	X
Benzene	X	X	X	X	X
Berylium	X				
Cadmium	X				
Carbon Tetrachloride			X		
Chlorobenzene				X	
Chloroform			X		
Chromium	X				
Ethylbenzene	X	X	X	X	X
Ethyl Chloride (Chloroethane)				X	
Ethylene Dibromide					
Ethylene Dichloride (1,2-Dichloroethane)					
Ethylidene Dichloride (1,1-Dichloroethane)					
Formaldehyde	X	X	X	X	X
Hexane	X				
Lead	X				
Manganese	X				
Mercury	X				
Methyl Chloroform (1,1,1-Trichloroethane)			X		
Methylene Chloride		X		X	
Naphthalene	X			X	X
Nickel	X				
POMs (PAHs)	X			X	
Propylene Dichloride (1,2-Dichloropropane)					
Selenium	X				
Styrene		X			
Tetrachloroethylene (Perchloroethylene)			X		
Toluene	X	X	X	X	X
Trichloroethylene			X		
Vinyl Chloride		X	X		

Test Protocol (1)

- Goal for Test Protocol:
  - Develop protocol to ensure operating conditions of RICE are addressed and recorded during emissions testing -- effects of operating conditions on emissions is a key data gap in existing data
  - Status:
  - Revised protocol e-mailed to all members prior to meeting
  - Issues raised by Bob Stachowicz at last meeting addressed
  - Other changes made to make the protocol more general
    - target pollutants removed from protocol -- these will be determined by the RICE Work Group
    - test methods removed from protocol -- these will be determined by the RICE Work Group

Test Protocol (2)

Test Procedures:

- Engine expert on site during all testing
- Initial Baseline Testing:
  - » all scheduled maintenance up to date
  - » engine is in a reasonable, repeatable state of health and tune consistent with good operating practices
    - particular attention to ignition/injection system
    - all engine adjustments per manufacturer's specifications
  - » operation at rated speed and torque

Test Protocol (3)

Test Procedures (continued):

- Generic Test Matrix:
  - » four corners of torque/speed envelope (runs 1-4)
  - » air/fuel ratio sensitivity (run 1, 5-6)
  - » potential for highest formaldehyde concentration (run 7)
  - » potential for lowest formaldehyde concentration (run 8)
  - » air manifold temperature sensitivity (run 1, 11-12)
  - » injection and spark timing sensitivity (run 13-14)
  - » engine balance sensitivity (run 1, 15-16)

☆ exhaust emissions from engines with after-treatment emissions control devices should by measured both before and after control devices

Changes to include ignition timing variation in test matrix:

- Section 7.2.1 added ignition timing sensitivity to bullets (with referenced tests) and changed tests for engine balance sensitivity to 15 and 16.
- Section 7.2.2.1 added note that ignition timing cannot be easily adjusted for diesels. Therefore, runs 13 and 14 do not apply.
- Section 7.2.2.2 added note (similar to above) for dual fuel engines.
- Test Matrix Table, added settings for ignition timing. Added runs 13 and 14 to vary ignition timing.

Run #	Speed	Torque	Air/Fuel	Timing	AMT	JWT
1	H	H	N	S	S	S
2	H	L	N	S	S	S
3	L	L	N	S	S	S
4	L	H	N	S	S	S
5	H	H	L	S	S	S
6	H	H	H	S	S	S
7	H	L	H	S	S	S
8	L	H	L	S	S	S
9	H	H	N	S	L	S
10	H	H	N	S	H	S
11	H	H	N	S	S	L
12	H	H	N	S	S	H
13	H	H	N	L	S	S
14	H	H	N	H	S	S
*Notes:	H, L to be determined based on operating range and control flexibility.	H, L to be determined based on operating range and control flexibility.	N = Nominal reqd. to satisfy emissions H = High value lowering emissions ≈25% L = Low value raising emissions ≈25%	S = Set point H = High of set point changing emissions ≈±25% L = Low of set point changing emissions ≈±25%		

<u>{Note: Should we consider incorporating parts of the information collection request we developed in January as part of any actual test program or to help us qualify which engines would be tested if we get approval from the CC / EPA? Specifically, I would think that Part I: General Facility Information, Part II: Stationary Reciprocating Internal Combustion Engine Information (largely the earlier Engineering Information part), and Part III: Typical Operating Information could be useful.}</u>

Test Protocol (4)

Engine Parameter Data to be Recorded:

- minimum data:
  - engine speed
  - engine torque or load
  - spark or injection timing
  - intake manifold pressure
  - intake manifold temperature
  - fuel flow rate
  - air flow rate
- other data:
  - intercooler water temperature, if so equipped
  - inlet air temperature (ambient)
  - inlet air pressure (ambient)
  - ambient humidity
  - exhaust manifold pressure
  - turbocharger speed
- where available and/or applicable:
  - average peak combustion pressure
  - location of peak combustion pressure
  - standard deviation of the peak combustion pressure
  - individual cylinder exhaust temperatures

Test Protocol (5)

Data Reduction:

» fuel flow

» exhaust flow (O_2 balance)

» exhaust flow (C balance)

» air flow

» air/fuel ratio

» fuel/air equivalence ratio

» brake specific fuel consumption (BSFC)

» emissions mass rates (NO_x, CO, THC, & HAPs)

» brake specific emissions rates (NO_x, CO, THC, & HAPs)

Proposal for Consensus

- Emissions Subgroup proposes that the test protocol, as drafted, will be a component of the plan for RICE emissions testing under ICCR
- Once specific engine categories for testing are determined, RICE Work Group will use the test protocol to identify:
  - appropriate tests in the matrix for each engine category
  - appropriate engine parameter data to be collected for each engine category

Schedule for RICE Test Plan

- Complete protocol   July 24 WG mtg
- Identify test methods   July 24 WG mtg
- Begin work on categories of RICE and controls to be tested   July 24 WG mtg
- Begin work on methodology to prioritize testing July 24 WG mtg
- Complete list of RICE and controls August 1997
- Complete prioritization methodology August 1997
- Complete test plan   September 1997

RICE Test Plan: Work Group Discussion & Decision-Making on Remaining Issues

Long Beach, California
July 24, 1997

Topics

- Remaining test plan issues
  - Categories of RICE, fuels, control devices to be tested
  - Test methods that will be used to quantify HAPs and criteria pollutants (working with T&M Work Group)
  - Methodology to prioritize emissions testing if limited testing funds are available
- Status of remaining Issues
- Resources available and possible approaches
- Next steps to complete

Categories of RICE, Fuels, and Controls (1)

- Goal for Categories of RICE, Fuels, and Controls:
  - Identify all categories of RICE, fuels, and controls that will be tested for emissions under ICCR
- Status:
  - Preliminary list of engine, fuel, and control categories included in original generic test plan removed -- Work Group to determine engines, fuels, and controls to be tested
- Resources:
  - Work Group expertise and literature information
  - Preliminary list of engine, fuel, and control categories
  - Engines, fuels, and controls reported in emissions database
  - Engines, fuels, and controls reported in population database

Categories of RICE, Fuels, and Controls (2)

- Possible features to determine categories:
  - Fuels used in stationary source applications
  - Engineering characteristics that may affect emissions
  - Engineering characteristics that may affect controls
  - Controls that may reasonably reduce HAPs
  - Categories of engines in existing emissions database
  - Categories of engines in existing population database

Next Steps: Categories

- Compare preliminary categories to:
  - engines, fuels, and controls in emissions database
  - engines, fuels, and controls in population database
    - databases may also provide inputs for prioritization
- Develop revised list of categories for Subgroup review by August 15, 1997
- Circulate final list of categories to Work Group for review by August 29, 1997

Test Methods (1)

- Goal for Test Methods:
  - Identify appropriate test methods to measure all listed pollutants -- try to maximize coverage while minimizing costs to extent possible
- Status:
  - Preliminary list of test methods developed by subgroup --
    2 methods, FTIR and TO-14, cover nearly all pollutants
- Resources:
  - Work Group expertise and literature information
  - Test methods reported in emissions database
  - List of methods, with preliminary costs, from Testing and Monitoring Work Group

Test Methods (2)

- Remaining Issues:
  - Costs associated with FTIR
    - possible use of modified CARB 430, Celanese, or Ashland methods instead of FTIR
  - Need for additional method to measure Naphthalene and POMs (PAHs) -- diesel, natural gas, & propane
    - SVOST (SW-846 0010, CARB 429, or equivalent)
  - Need for additional method to measure metals -- diesel
    - Method 29 (11 metals)

Next Steps: Test Methods

- Determine costs to add SVOST if already on site to perform EPA 18/TO-14 and aldehyde testing
  - ask Testing & Monitoring Work Group for assistance
- Develop list of test methods, with costs, for Subgroup review by August 15, 1997
- Circulate final list of test methods to Work Group for review by August 29, 1997

Prioritization (1)

- Goal for Prioritization:
  - Identify method to prioritize testing in case limited funds are available
- Status:
  - EPA has indicated that engines with controls will be top priority for the Agency
- Resources:
  - Work Group expertise and literature information
  - Engines, fuels, and controls reported in emissions database
  - Engines, fuels, and controls reported in population database

Prioritization (2)

- Possible Inputs:
  - Controls present are in a category of controls reasonably anticipated to reduce HAPs
  - Category of engine represents a significant portion of the existing population
  - Emissions from the category of engine are significant
    - » compared to emissions from entire population of engines
    - » compared to other individual engines

Next Steps: Prioritization

- Compare results of preliminary methodology to prioritize testing with data included in emissions and population databases
- Develop prioritization for Subgroup review by
  August 29, 1997
- Circulate prioritization to Work Group for review by September 3, 1997

ATTACHMENT V

GENERIC TEST PROTOCOL

Generic Test Protocol

1.0 Introduction

In support of ICCR, the Emissions Subgroup has been asked to develop an emissions test plan for future emissions testing (both air toxics and criteria pollutants) of stationary Reciprocating Internal Combustion (RIC) engines. The following generic test protocol will be one component of the emissions test plan. The goal of this generic test protocol is to ensure that adequate data regarding the operating status of the IC engines is gathered during the emissions testing.

2.0 Engine Classification

Stationary reciprocating internal combustion engines come in a wide variety of makes and models utilizing both liquid and gaseous fuels in diverse applications. To assist in classifying and characterizing engines in support of air toxics testing, the various types can be categorized according to:

scavenging cycle
ignition system
fuel type
emissions control techniques
driven equipment

A brief description of each of these categories is contained in section 2.1 followed by a listing of the most common combinations of categories and sub-categories.

2.1 Categorizing Engines

A brief description of each engine category and associated equipment configurations follows.

2.1.1 Scavenging Cycles

Reciprocating internal combustion engines utilize either two stroke cycle (2SC) or four stroke cycle (4SC) scavenging. The efficacy of the scavenging cycle will impact the trapped air/fuel charge in turn impacting air toxics formation. A summary of the various scavenging cycles and equipment configurations follows.

2.1.1.1 Four Stroke Cycle

4SC is the most familiar engine type due to its use in vehicular applications. A 4SC engine undergoes four distinct events or "strokes". Each cycle consists of; intake, compression, power and exhaust. Due to the pumping action of the intake and exhaust strokes, 4SC engines are self aspirating or "scavenging"[1]. 4SC engines operating at fresh air charge densities induced only by this inherent pumping action are often referred to as Naturally Aspirated (NA). Inasmuch as maximum power delivery is limited by the air supply, 4SC NA engines tend to operate near or slightly rich of stoichiometry, hence the appellation "rich burn".

In general, financial and performance considerations require that large (.>500 BHP) stationary 4 SC engines operate at specific outputs 2-4 times that obtainable with NA alone. Therefore these engines utilize an auxiliary air compressor to increase the charge density at the engine intake. The most common method is to utilize an exhaust-gas-driven turbine to drive the compressor, usually called a "turbocharger". In addition, to maximize the fresh air charge density, most 4SC turbocharged (4 SC TC) engines utilize an aftercooler or intercooler to remove the heat of compression from the fresh air charge. Typically, mechanical and/or thermal loading limits the output of 4SC TC engines. 4 SC TC engines can operate from rich of stoichiometry to more than twice as lean as stoichiometry (over 100% excess combustion air). A common method used to differentiate between “rich burn” and “lean burn” engines is with percentage oxygen in the exhaust stream. Several regulatory agencies have adopted a value of 4% oxygen in the exhaust as the defining limit for “rich burn” engines. An engine with more than 4% exhaust oxygen is classified as “lean burn”. In point of fact, most “lean burn” engines manufactured today contain at least 7% exhaust oxygen.

2.1.1.2 Two Stroke Cycle

To maximize power output/density, 2SC engines eliminate the intake and exhaust "pumping" strokes of 4SC engines, retaining only the compression and power strokes. Consequently, an auxiliary device is required to "scavenge" the engine. In their simplest form this may consist of pumping off the underside of the piston or the addition of one or more scavenging pump cylinders to the same crankshaft connecting the power cylinders. In more sophisticated applications gear or motor driven blowers may supply scavenging air. Typically, due to inherent limitations in 2SC scavenging, these pump scavenged (2SC PS) or blower scavenged (2SC BS) 2SC engines operate somewhat lean of stoichiometric and are also classified as "lean burn".

Like their 4SC brethren, financial and performance considerations (in particular the

[1] The word “scavenge” in this use refers to the removal of spent exhaust gases and their replenishment with a fresh air charge.

parasitic load of crank driven pumps/blowers), require that larger more modern stationary 2 SC engines utilize turbochargers and intercoolers to increase charge air density and hence specific output. These 2SC TC engines typically operate well lean of stoichiometric, similarly receiving the "lean burn" appellation.

2.1.2 Ignition System

Internal combustion engines require an initial energy source to "light off" or ignite the air/fuel mixture. Both 2SC and 4SC internal combustion engines utilize one of two methods, Spark Ignition (SI) or Compression Ignition (CI). The timing and energy input of the ignition system impact the initiation and rate of combustion, which in turn impact air toxics formation via flame propagation and penetration. A summary of ignition sub-categories follows.

2.1.2.1 Spark Ignition (SI)

SI engines utilize a "spark" generated by a spark plug and associated electronics to initiate combustion. Traditionally, one or more of these spark plugs were mounted directly in the combustion chamber. While simple, when applied to larger bore engines, such "Open Combustion Chamber" (SI-OCC) systems result in significant combustion instability and can operate only at moderately lean air/fuel ratios. To extend the lean limit (and thereby reduce NO_x emissions while improving efficiency) Original Engine Manufacturers (OEMs) introduced two stage combustion including a rich initial phase which has sufficient energy to light off the very lean secondary phase. Usually the rich phase is ignited by the spark in a "Pre-Combustion Chamber" (SI-PCC).

Recently, several aftermarket manufacturers have offered alternative electrical based ignition systems such as plasma jets. Typically these High Energy (HE) ignition systems operate in an OCC, and will be referred to as HE-OCC in this document.

2.1.2.2 Compression Ignition (CI)

Compression Ignition engines operate at significantly higher compression ratios than SI engines, with the resultant heat of compression raising the temperature of the trapped air or air/fuel charge to $\approx 800^{o}$F or more. Fuel (usually liquid) injected into this hot compressed gas then spontaneously vaporizes, disassociates and ignites. Often CI engines are referred to as "diesel" engines after the originator and patent holder of the method[2]. While some vehicular diesel engines utilize a pre combustion chamber to assist in ignition, particularly at part load, all large stationary CI "diesels" have OCCs to

[2] Rudolph Diesel originally wanted to utilize coal dust as the fuel but soon changed to liquid fuels when the former burned uncontrollably and proved excessively abrasive.

maximize efficiency and performance.

The other major type of CI engine scavenges or injects gaseous fuels into the combustion chamber with the fresh air charge and then utilizes a small "pilot injection" of liquid fuel (usually No. 2D) to ignite the mixture. Typically called "dual fuel" or "gas-diesel" engines, the less expensive gaseous fuel usually provides 90-99% of the input energy while the more expensive liquid fuel provides the balance. Originally, dual fuel engines were simple conversions of OCC diesel engines which maintained the ability to operate on "full diesel" (i.e. 100% liquid fuel). While offering favorable NO_x emissions in this configuration (.4-5 g/BHP-HR) subsequent regulatory pressure to further reduce emissions resulted in several OEMs offering such engines fitted with PCCs to reduce the pilot fraction to ≈1% or less.

By their nature (i.e. ignition via heat of compression), all stationary CI engines are inherently "lean burn", usually utilizing turbochargers and intercoolers to achieve the desired fresh air density.

2.1.3 Fuel Type

Fuel type and associated mixing impact initiation, rate and completeness of combustion which in turn impacts air toxics formation. Stationary internal combustion engines utilize either liquid or gaseous fuels as follows.

2.1.3.1 Liquid Fuels

With the exception of extremely small co-generation applications (≈<100 kW) liquid fueled SI engines are seldom utilized in stationary applications. Rather, all stationary liquid fueled engines operate on the CI cycle. However, due to the simplicity and robustness of this ignition method, CI engines can operate on a wide variety of liquid fuels ranging from light distillates such as No. 2 fuel oil to residuals from the refining process which are virtually solid at room temperature, sometimes called residual or "heavy" fuel.

2.1.3.2 Gaseous Fuels

Virtually (if not) all stationary SI engines operate on gaseous fuels while many stationary CI engines utilize gaseous fuels as the primary energy input. In both cases, the vast majority of units utilize either field or pipeline quality Natural Gas (NG).

A number of SI and CI engines, usually in "co-generation" applications, operate on other gaseous fuels typically the by-product of some unrelated process. These include "Digester Gas" (DG) from the treatment of wastewater, "Process Gas" (PG) from chemical refining processes and "Landfill Gas" (LFG) from solid waste in landfills.

2.1.4 Emissions Control Strategies

In general, emissions control strategies for stationary internal combustion engines focus on NO_x reduction, either by altering the combustion process or exhaust after-treatment. While none of these strategies currently focus on the formation/reduction of air toxics, they may have an impact. Therefore Emissions Control Strategies are included as an engine category as summarized below.

2.1.4.1 Altered Combustion Process

Most larger "lean burn" stationary reciprocating engines subject to emissions limitations utilize some form of altered combustion process to reduce NO_x emissions, which could also impact (most likely increasing) the formation of air toxics. This usually includes parametric adjustments to lean out the air/fuel mixture, often in conjunction with PCCs on SI engines to obtain minimum NO_x. Other NO_x reducing parametric adjustments include retarded injection or ignition timing and reduced charge temperatures.

A few engines may utilize more exotic forms of combustion modification including Exhaust Gas Recirculation (EGR) or Water Injection (WI), the latter on diesels only.

2.1.4.2 Exhaust After-treatment

In some applications, stationary reciprocating engines may utilize exhaust gas after-treatment (i.e. catalytic conversion) to reduce emissions, again primarily NO_x. This generally consists of Non-Selective Catalytic Reduction (NSCR)[3] on "rich burn" gaseous fueled engines, or Selective Catalytic Reduction (SCR) in conjunction with a reducing agent on "lean burn" engines. In a few applications natural gas lean burn engines may utilize oxidation catalysts to eliminate CO while some NO. 2D fueled CI engines utilize oxidation catalysts to reduce odor.

The impact of catalytic after-treatment on air toxics is uncertain. In some situations beneficial oxidation of air toxics may occur, however, "before" and "after" catalyst testing <u>would be necessary to verify this likelihood</u>.

2.1.5 Driven Equipment

While the driven equipment generally does not impact air toxics formation per se, the driven equipment does affect the operating speed and torque profile. In particular,

[3] Sometimes referred to as “three way” (i.e. CO, THC and NO_x) conversion.

operation at high speeds and low torque may encourage air toxics formation while reduced speed and high torque operation can reduce air toxics formation. Relevant comments follow.

2.1.5.1 Reciprocating compressors

Probably the most common application of stationary engines, engine driven reciprocating compressors are utilized in the "Oil & Gas" industry to gather and process natural gas and in the "Natural Gas Pipeline" to transport natural gas to end users. Typically these engines operate over a range of varying speed (≈80-100% of rated) and torque (≈90-120%). Depending on various parametric settings (i.e. air/fuel, ignition timing, etc.) over the operable range of speed and torque, air toxics formation could vary considerably. Therefore air toxics testing of engines driving reciprocating compressors should minimally include the four speed/torque corners (i.e. max speed/max torque, min speed/min torque, etc.).

2.1.5.2 Generators

The next most common application, synchronous AC generators driven by stationary engines, is utilized to:

- provide prime power in remote locations (i.e. Hawaii, Alaska, etc.)
- provide peak/municipal power to the local grid in populated areas
- "co-generate" power in conjunction with waste heat recovery with the possibility to provide excess power to the local grid in populated areas
- provide emergency power[4] for hospitals, airports, data centers, nuclear power plants, etc.

By their nature AC generator drives must operate at fixed (synchronous) speed. Therefore, only the torque varies, typically over the range of 75-100% of rated. Other than air/fuel ratio and spark timing on gaseous fueled engines, parametric variation over this range tends to be limited. At most, air toxics emissions should be tested at minimum and maximum torque at possible timing extremes.

2.1.5.3 Miscellaneous

After reciprocating compressors and generators, most remaining stationary engines drive rotating compressors, blowers, pumps etc. In general, these machines follow a quadratic relationship between speed and torque (i.e. the torque absorbed is proportional to the square of the speed). Worst case air toxics formation should

[4] Typically the annual operating hours of these units are low enough to fall below other regulatory mass emissions rates.

generally occur at either the minimum or maximum normal operating speed.

2.2 Typical Category Combinations

While there are approximately 3,000 combinations of the above categories and sub-categories listed in section 2.1, the majority of the combinations are not viable. Rather, approximately 40 combinations probably cover 99% of the stationary engine population, of which ≈20 combinations are "typical". Moreover, probably 90% of the engine population falls into less than 10 combinations.

The IC Engine Work Group of ICCR will determine the IC engine types and control devices that will be tested.

3.0 Test Overview

The purpose of the testing as defined in this outline test plan is to sufficiently characterize HAPs emissions for RIC engines representing the majority of the engine population. By categorizing engines into specific families or groups, as defined in Section 2.0, and conducting testing to fully characterize HAPs emissions for engines in those categories, this objective can be accomplished.

Specifically, the testing will accomplish the following:

Characterize HAPs emissions at normal operating conditions (i.e. load, speed, etc.).

Characterize the sensitivity of HAPs emissions to specific known "driving" parameters such as air/fuel ratio, ignition or injection timing, charge air temperature, jacket water temperature (because of its impact on cylinder wall temperature and further heat transfer to cylinder contents) and fuel type/mix.

Define probable highest and lowest level of HAPs emissions from the engine based on the engine's operating envelope.

While HAPs emissions, specifically formaldehyde, are the primary interest of this test plan, criteria pollutant emissions (NOx, CO, THC) and dilutant gas (O2, CO2) measurements will also be made. Additionally, engine operating and performance data must be recorded in order to fully analyze and validate the emissions data.

Emissions test methods to quantify the concentrations of HAP and criteria pollutant emissions will be determined by the IC Engine Work Group.

4.0 Exhaust Sampling System Descriptions

Specific protocols for sample collection and the data acquisition systems will be submitted to the IC Engine Work Group for review and approval prior to testing. In general, the samples will be collected as described below.

4.1 Criteria Pollutant Reference Method System

Reference Method (RM) trailers will draw an exhaust sample via a probe installed downstream of the turbochargers if so equipped. The conditioned sample will then pass through a common manifold to criteria pollutant analyzers. Each analyzer will output a signal to a Data Acquisition System (RMDAQ) which will correct the data for drift and calculate mass and brake-specific emissions rates. The RMDAQ also will continuously hand the emissions analyzer data off to the database data acquisition system (DBDAQ).

4.2 HAPs FTIR System

HAPs FTIR trailers will draw exhaust from a train probe mounted adjacent to the RM probe. The sample is passed through the FTIR. The FTIR DAQ will perform the necessary Fourier analyses and then determines and displays/archives/prints the resultant emissions. The FTIR DAQ also will continuously hand the emissions data off to the DBDAQ.

5.0 Engine Parameter & Emissions Data Base Collection

Specific protocols for collecting engine parameter data and specifications for the data acquisition systems will be submitted to the IC Engine Work Group for review and approval prior to testing. Fuel analysis will be conducted for all emissions tests. In general, engine parameter data must meet the minimum requirements specified below.

5.1 Hardware Description

Must be able to pull all engine operating parameters as well as emissions (criteria and HAPs) into a common database (DBDAQ). May or may not be separate data acquisition system.

5.1.1 RM Data

Data sent by the RMDAQ may include:

NO_x (ppm)
CO (ppm)
THC (ppm)
CO_2 (%)
O_2 (%)

5.1.2 HAPs Data

The HAPs system will supply HAPs information. The HAPs DAQ will download its information DBDAQ. The HAPs Target Compound list will be determined by the IC Engine Work Group.

5.1.3 Engine Operating and Performance Parameters

The minimum data that will be transmitted to the DBDAQ includes:

Engine Speed
Engine Torque or Load
Spark or Injection Timing
Intake Manifold Pressure (IMP)
Intake Manifold Temperature (IMT)
Fuel Flow Rate
Air Flow Rate

Exhaust Manifold Temperature (upstream of TC if so equipped)
Jacket Water Temperature (JWT)

Other data may include:

Intercooler Water Temperature (IWT) if so equipped
Inlet Air Temperature (ambient)
Inlet Air Pressure (ambient barometer)
Ambient Humidity
Exhaust Manifold Pressure
Turbocharger Speed

In addition, the following data should be recorded where available and/or applicable:

Average peak combustion pressure
Location of peak combustion pressure
Standard deviation of the peak combustion pressure
Individual cylinder exhaust temperatures

5.2 Data Reduction & Collection

During actual testing, the DBDAQ will scan all inputs at a rate of 1 Hz and perform all relevant calculations continuously, including:

Fuel Flow
Exhaust Flow (O_2 Balance)
Exhaust Flow (C Balance)
Air Flow
Air/Fuel Ratio
F/A Equivalence Ratio
Brake Specific Fuel Consumption (BSFC)
Emissions Mass Rates (NO_X, CO, THC & HAPs)
Brake Specific Emissions Rate (NO_X, CO, THC, & HAPs)

Upon successful completion of each 10 minute test run (see below), the test director will archive the data on the DBDAQ hard drive, import the data into a preliminary Test Condition Summary Data Sheet and print a preliminary copy of the data for review and comparison with other test runs.

6.0 Test Coordination

6.1 Roles / Responsibilities

Relevant roles during the test include the following:

Test Director

The Test Director will be an engine expert which is approved by the IC Engine Work Group. The test director will coordinate all aspects of the test including engine operation, analyzer operation and calibration and assessment of the stability and suitability of engine performance. The test director will review and define required engine maintenance, tuning or adjustment and convey those requests to the Plant Liaison. The test director will elect when to start and stop the test runs and then assess the suitability of each individual run. The test director will generate, review and distribute all final Test Condition Summary Data Sheets and associated archives.

Performance Analyst

The performance analyst will perform analysis of the power cylinder balance and combustion stability and the compressor cylinder horsepower as requested by the test director. The analyst will also assist plant staff in balancing of the power cylinders and diagnosis of any combustion performance aberrations.

RM Operator

The RM operator will maintain and operate all criteria analyzers and related equipment up to and including the stack probe. The RM operator will coordinate pre and post test calibrations with the test director. The RM operator will also perform all post test drift correction calculations and provide the test director with all final drift corrected emissions values.

FTIR Operator

The FTIR operator will maintain and operate the FTIR and all related equipment after the stack probe. The FTIR operator will coordinate pre and post test calibrations with the test director. The FTIR operator will also perform all post test drift correction calculations and provide the test director with all final drift corrected emissions values.

Plant Liaison

Provided by the host company, the plant liaison will coordinate engine loading with gas control, direct the plant operators to set the engine to the desired condition, and arrange for the execution of any maintenance requested by the test director. The plant liaison is responsible for ensuring the engine and auxiliaries operate in a safe manner which will not compromise their life or operability or endanger the test team.

6.2 Execution of the Test Runs

6.2.1 Pre-test Preparation

At the beginning of each test day, the RM & FTIR operators will perform preliminary calibration of their instruments. The plant liaison will arrange for the calibration of all engine sensors as requested by the test director. The test director will walk down the engine and all systems with the plant liaison to ensure the unit is properly prepared for testing.

6.2.2 Engine Set-up

Prior to establishing a new test condition, the test director will review the desired test condition with the plant liaison who in turn will coordinate setting of the engine and auxiliaries to the desired condition.

The test director will then monitor engine operating and emissions parameters and assess stability and suitability of engine performance. The test director will define any required special engine adjustments and, when satisfied, direct the performance analyst to collect a set of readings. Reviewing the results, the director will define any required corrective action. Once satisfied, the test director will begin preparations for a test run.

6.2.3 Test Run

Once satisfied with the engine set-up, and confident the engine is operating at steady state at the desired condition, the test director will notify the RM and FTIR operators to perform calibrations (as required). Once complete, the test director will begin collecting 10 minute data sets with the DBDAQ, monitoring engine performance and engine speed and load stability throughout. The director will continue to collect data sets until at least three satisfactory runs are obtained at the desired test condition. Upon completion of all runs for a given condition (or as required) the test director will notify the RM and FTIR operators to perform post-calibrations (as required) to reestablish drift correction factors.

Upon completion of each test condition, the test director will generate and distribute a preliminary Test Condition Summary Data Sheet. At the end of each day, the RM and FTIR operators will generate final drift corrected emissions values which the test director will then incorporate in the final Test Condition Summary Data Sheet.

7.0 Test Procedures

7.1 Initial Baseline Testing

7.1.1 Engine Preparation, Instrumentation Setup, Calibration and Validation

Prior to initiation of the testing, confirm all scheduled maintenance for the engine and auxiliaries is up to date. Confirm that the engine is in a reasonable, repeatable state of health and tune consistent with good operating practices. Pay particular attention to the condition of the ignition/injection system. Install new spark plugs, replace or rebuild pre-combustion chamber check valves, clean and pop test fuel injector nozzles, etc., as applicable. <u>All engine adjustments, ignition/injection timing, fuel system, air system, etc., should be set per the manufacturer's specifications.</u>

Any additional sensors that are required for the testing must be installed. Calibrate all sensors providing engine control, performance and emissions parameter sensors. Confirm proper indication of each sensor value at the DBDAQ.

Start and operate the engine at rated speed and torque. Monitor all engine control, performance and emissions parameter sensor values and confirm credibility/validity. Perform hand calculations and cross checks of all calculated parameters such as fuel flow, BHP, BSFC, exhaust flow, emissions mass rates, etc. Take corrective action as required.

7.1.2 Engine Control System Shakedown

Operate the engine at various extremes of operation including the four corners of the torque / speed map as defined in Section 7.2 - Test Matrix.

At each condition, monitor the various control, performance and emissions parameters including speed, IMT, IMP, IWT, JWT, fuel flow, exhaust O2, etc. Confirm that the automation can control the engine over the operating range <u>with sufficient stability (commonly defined as an acceptable tolerance of speed and/or load variation around the desired mean values)</u> to obtain repeatable data. Investigate and resolve any instabilities, inconsistencies, problems, etc.

7.1.3 Engine Performance Repeatability Test

Operate the engine in equilibrium at rated speed and torque (baseline condition). Collect three or more test runs. Disturb the engine by altering one or more control parameters and operate at that condition for at least one hour. Return the unit to rated speed and torque. Once equilibrium is obtained, collect three or more test runs. Repeat the baseline test for each day of testing and compare to the initially defined baseline runs. Determine overall non-repeatability in baseline operation and determine typical variations in control, performance and emissions parameter values.

7.2 Test Matrix

The mapping test matrix will generate a database incorporating the effects of varying speed, torque, air/fuel ratio, air manifold temperature, jacket water temperature, timing, fuel types and varying degrees of combustion imbalance as applicable to the specific engine's operating envelope.

An engine may be in stable operation and not conform to the OEM's balance specification. Engine balance is commonly defined in terms of the difference in peak combustion pressure or exhaust temperature between the highest value and lowest value cylinders of the engine. An engine with acceptable balance has the maximum difference(s) within a set OEM specification. To determine unbalance requires the proper instrumentation to measure these pressures and/or temperatures on the individual cylinders. To unbalance an engine (ref. 7.2.1, runs 13-14) requires an engine with the provision to adjust individual cylinder compression or ignition timing.

7.2.1 Generic Test Matrix

The most widely ranging generic test matrix consists of:

Four corners of the torque / speed envelope (runs 1-4)
Air / fuel ratio sensitivity (run 1, 5-6)
Potential highest formaldehyde concentration (run 7)
Potential lowest formaldehyde concentration (run 8)
Air manifold temperature sensitivity (run 1, 9-10)
Jacket water temperature sensitivity (run 1, 11-12)
Injection or spark timing sensitivity (run 13-14)
Engine balance sensitivity[5] (run 1, 15-16)

Runs 15-16 not shown in matrix. Same as run 1 but with poorer state of engine balance in increments to increase NOx emissions by 5 and 10% respectively.

In addition, for the case of multi-fueled engines (such as "dual-fuel" CI engines or liquid fuel CI engines operating on No. 2D or Heavy Fuel) all testing shall be performed on the primary fuel. Then, test conditions 1, 7 & 8 should be repeated on the secondary fuel. In addition, if an engine regularly operates on an intermediate mix of the two fuels (e.g. 50%

[5] Runs 1-12 conducted with engine balance within OEM specification of good balance.

NG-50% DG), then test conditions 1, 7 & 8 should be repeated at this fuel mixture(s) also.

Finally, exhaust emissions from engines fitted with after-treatment emissions control devices should be measured both before and after that emissions control treatment device.

7.2.2 Engine Specific Test Matrix Considerations

The above matrix applies to the most widely varying engine operation, typical for example of NG fueled engines in pipeline operation. However, many engine categories will not require the full test matrix. Rather, due to a reduced ability to vary parameters, an abbreviated matrix will apply. Specific examples follow.

7.2.2.1 Liquid Fueled CI Engines (Diesels)

Since liquid fueled CI engines utilize the maximum available charge air the air/fuel ratio is not variable for a given speed and torque. Test conditions 5-8 are not applicable. In addition, changing ignition (injection) timing is generally quite difficult and time consuming. Therefore, test conditions 13 and 14 are not applicable.

7.2.2.2 Liquid and Gaseous Fueled CI Engines (Dual Fuel or Gas-Diesel)

Changing ignition (injection) timing in liquid & gaseous fueled CI engines is generally quite difficult and time consuming, therefore test conditions 13 and 14 are not applicable.

7.2.2.3 Synchronous Generator Drives

Synchronous generators do not vary speed. Test conditions 3, 4, 7 & 8 are not applicable.

7.2.2.4 Pumps/Blower Drives

The torque absorbed by a pump or blower is generally determined by the speed. Test conditions 2 & 4 are not applicable.

Run #	Speed	Torque	Air/Fuel	Timing	AMT	JWT
1	H	H	N	S	S	S
2	H	L	N	S	S	S
3	L	L	N	S	S	S
4	L	H	N	S	S	S
5	H	H	L	S	S	S
6	H	H	H	S	S	S
7	H	L	H	S	S	S
8	L	H	L	S	S	S
9	H	H	N	S	L	S
10	H	H	N	S	H	S
11	H	H	N	S	S	L
12	H	H	N	S	S	H
13	H	H	N	L	S	S
14	H	H	N	H	S	S
*Notes:	H, L to be determined based on operating range and control flexibility.	H, L to be determined based on operating range and control flexibility.	N = Nominal reqd. to satisfy emissions H = High value lowering emissions ≈25% L = Low value raising emissions ≈25%	S = Set point H = High of set point changing emissions ≈±25% L = Low of set point changing emissions ≈±25%		

{Note: Should we consider incorporating parts of the information collection request we developed in January as part of any actual test program or to help us qualify which engines would be tested if we get approval from the CC / EPA? Specifically, I would think that Part I: General Facility Information, Part II: Stationary Reciprocating Internal Combustion Engine Information (largely the earlier Engineering Information part), and Part III: Typical Operating Information could be useful.}

ATTACHMENT VI

POPULATION DATABASE ENHANCEMENT ACTIVITIES
PRESENTED BY JENNIFER SNYDER

Reciprocating Internal Combustion Engines Work Group

Population Database - Refinement

July 24, 1997

RICE Population Database

Refinement Activities

- Goals:

  Clean up the population database

  Summarize and review the information in the population database

- Products:

  Population database more applicable to Engines

  Simplified population database

- Schedule:

  July to September, '97

  (All Refinement Activities should be <u>*reproducible*</u> *for documentation purposes)*

RICE Population Database

- Completed Refinement Activities
  - Identified Non-Engines units

    Incorporated a reference code to identify the appropriate ICCR Source Category for each record

    (X-non ICCR; B- Boiler; I- Incinerators; P-Heaters; R- RICE; and T- Turbine)

    Forwarded non-engines to appropriate ICCR Source Work Groups

    (A total of 584 records were identified as non-engines)

RICE Population Database

¨ Completed Refinement Activities (Cont.)

- Extracted engine information from text fields

  "Combustor Description" - 16,712 records

  "Fuel Type" - 3,662 records

- Extracted information specific to engines, some not previously referenced in the database

  Make, Model, Size & units, Fuel Type, Rich/Lean Burn, 2/4 Stroke, and Number of Units

- Assigned SCCs to engines with incomplete SCCs

  Used the text fields to identify the unit - 50 records

RICE Population Database

- Completed Refinement Activities (Cont.)
  - Identified engine's fuel type from the SCC Code

    Criteria: Fuel Type > Combustor Description > SCC

    (All extracted/updated information are compiled in separate tables which are mergable with Version 2)

  - Obtained engine information from WG members

    Information supplied in hard copies, text files, word processing files, and databases

    Converted and compiled information into mergable format

RICE Population Database

- Completed Refinement Activities (Cont.)
  - Developed "Short List of Fields"
    - *All activities are well documented for data integrity*
      - *Almost all activities are in electronic form*
      - *Manual activities are referenced in "Memos" to the files*
      - *Incorporated a source code for each piece of information*

RICE Population Database

- Results:
  - Total Number of Engines: 28,162

RICE Population Database

- Results (Cont.)
  - Control Device Information Summary:
    Criteria I: Only "000" considered as "No Equipment"
    Criteria II: "000" or "Null" as "No Equipment"

  - Notes:
    Need to check on some of the referenced control devices (e.g., bag filters for NG unit)
    Did not have time to reflect increments of "Null" as "No Control"
    Texas and Louisiana indicated that "Null" means "No Control" - Need to check with remaining states and get proper documentation

RICE Population Database

- Results (Cont.)
  - Notes (Cont.):

    Contact separate sites or request WG members to assist in verification process

  - Short List of Fields/Relevant Fields:

    Information grouped in 4 sections:

    -Facility Information - ID, Name, Address, Contact

    -Combustion Unit Information - Make, Model, Size, Oper.

    -Subcategory Information - Asp., #Strokes, RB/LB, Service

    -Emissions Information - Pollutant, Control Device, Efficiency., Emission Method Code, Permit Info

RICE Population Database

- Next Steps:
  - Complete the Make and Model table for Engines

    Some records are missing:

      Size information

      Number of Cycles

      Combustion Class

RICE Population Database

¨ Next Steps (Cont.):

- Convert engine size to a standard unit

  Engine size units provided in energy input units or power output units

  From the 1993 ACT, the following efficiencies are provided;

Rich-Burn SI Engines:	*34.4% (31 - 38)*
Lean-Burn SI Engines:	*33.8% (29 - 38)*
Diesel Engines:	*38.4% (38 - 41)*
Dual-Fuel Engines:	*37.6% (37 - 41)*

  WG member information reflect lower efficiencies:

2 Stroke SI Engines:	*28% (20 - 36)*
4 Stroke SI Engines:	*29% (21 - 35)*

RICE Population Database

- Next Steps (Cont.):
  - Resolving the issue of "Null" in the Control Device Code
  - Compare and update with inventory information provided by WG members

    TNRCC - Beaumont and Houston non-attainment areas

    Ventura County
  - Update with Louisiana and New York Data
  - Compare and update with additional information from other sources, including: DOD, DOE, & API
  - Develop "Final Population Database" by merging information from listed sources